

# Computer Models

EES 3310/5310

Global Climate Change

Jonathan Gilligan

Class #16: Monday, March 1 2021

# Climate and Economy

# Climate and Economy

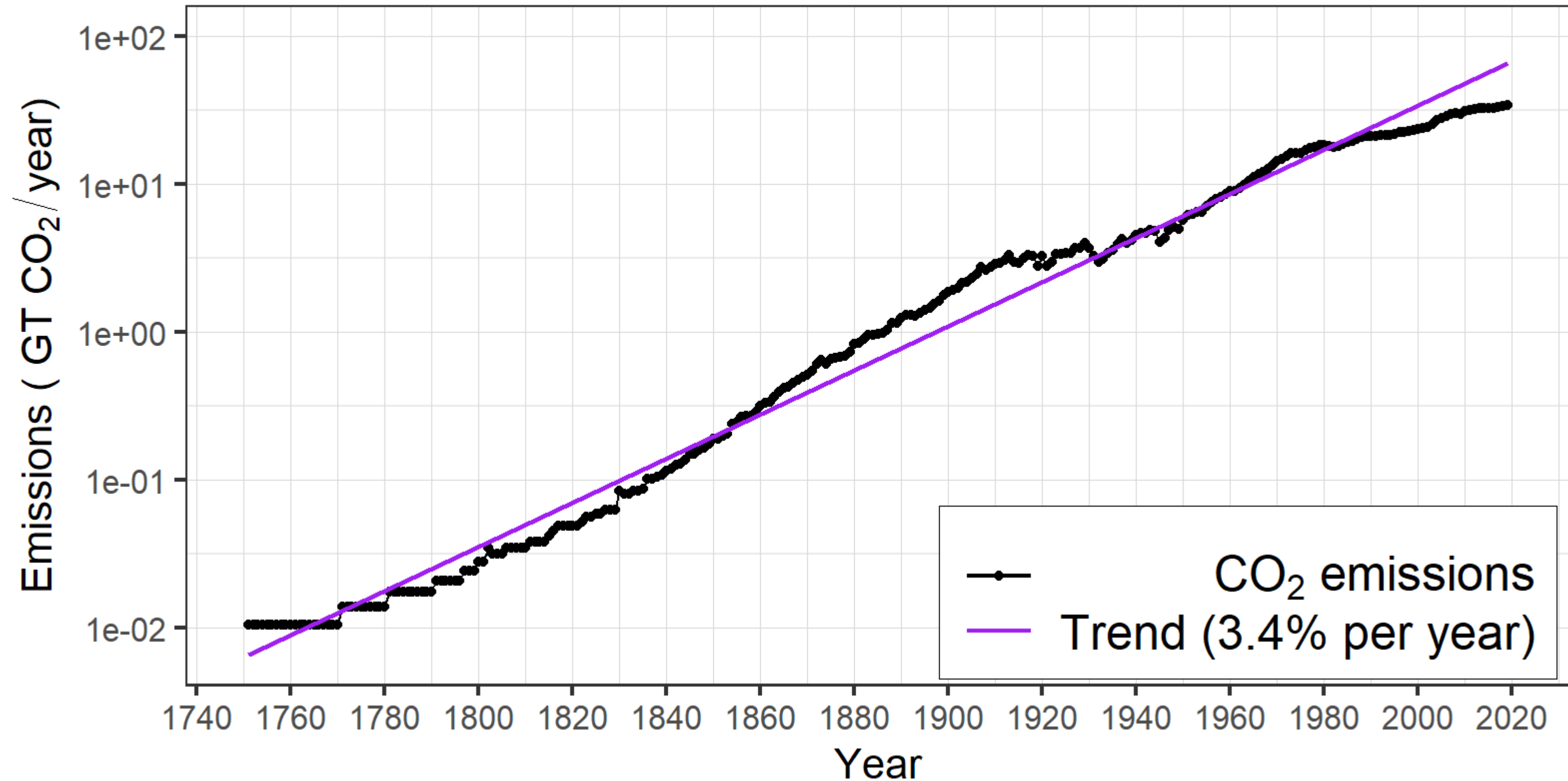
## How well do markets manage global warming?

- How well do markets manage supply and price of bread?
- What is different about global warming?
- Externalities:
  - What is an externality?
  - Are externalities good or bad?
  - What challenges to they pose for markets?
  - How can market-based economies manage externalities better?

Discuss for 5 minutes in breakout rooms

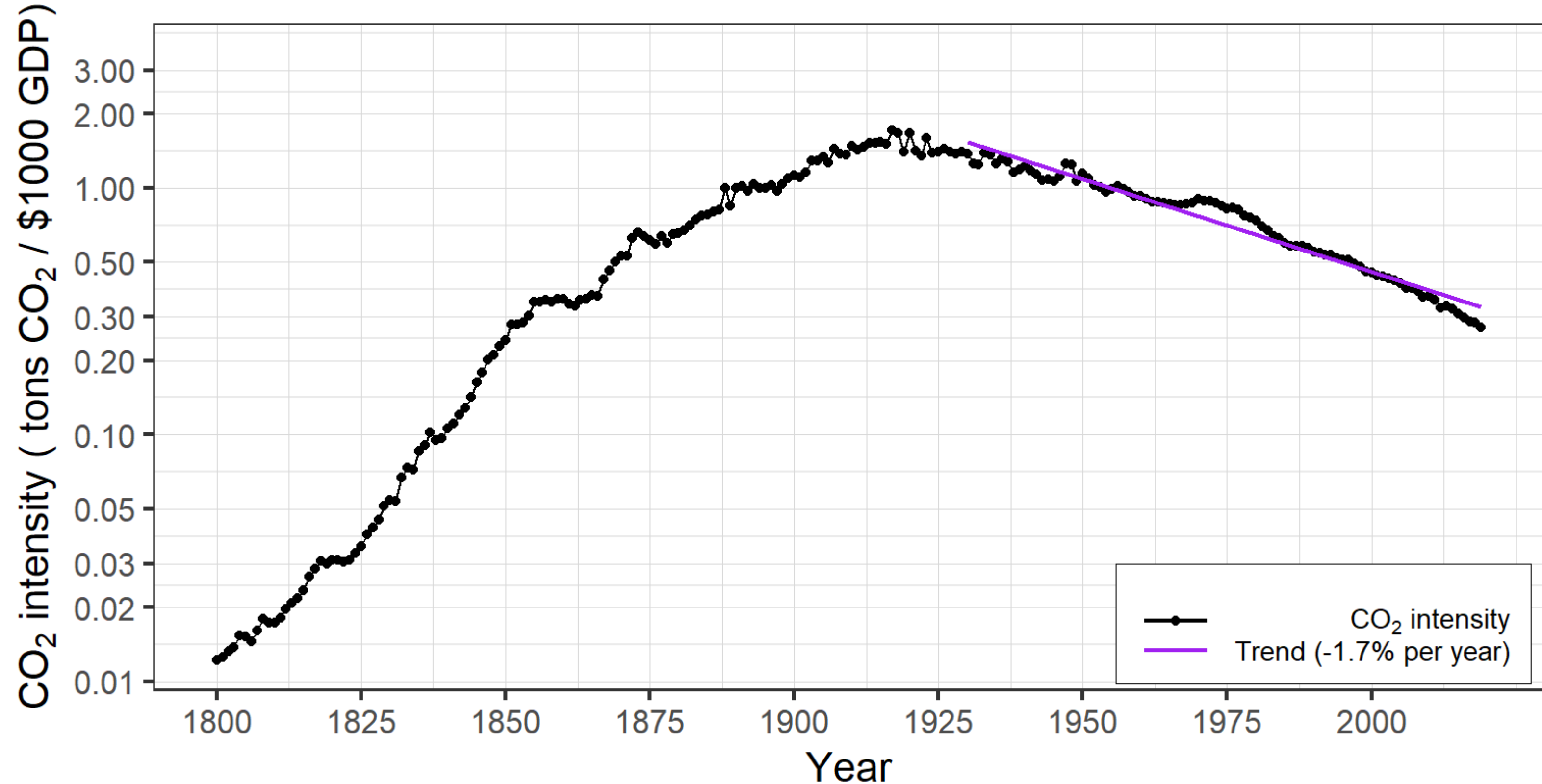
# Energy, Economy, Emissions

Global CO<sub>2</sub> emissions 1751-2019



# Energy, Economy, Emissions

CO<sub>2</sub> intensity of the US economy 1800-2019



# Kaya Identity

# Kaya Identity

$$P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} = F,$$

where

$F$  = CO<sub>2</sub> emissions

$E$  = energy use

$G$  = gross domestic product

$P$  = population

# Kaya Identity

$$\begin{aligned} F &= P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} \\ &= P \times g \times e \times f \end{aligned}$$

where

$P$  = population

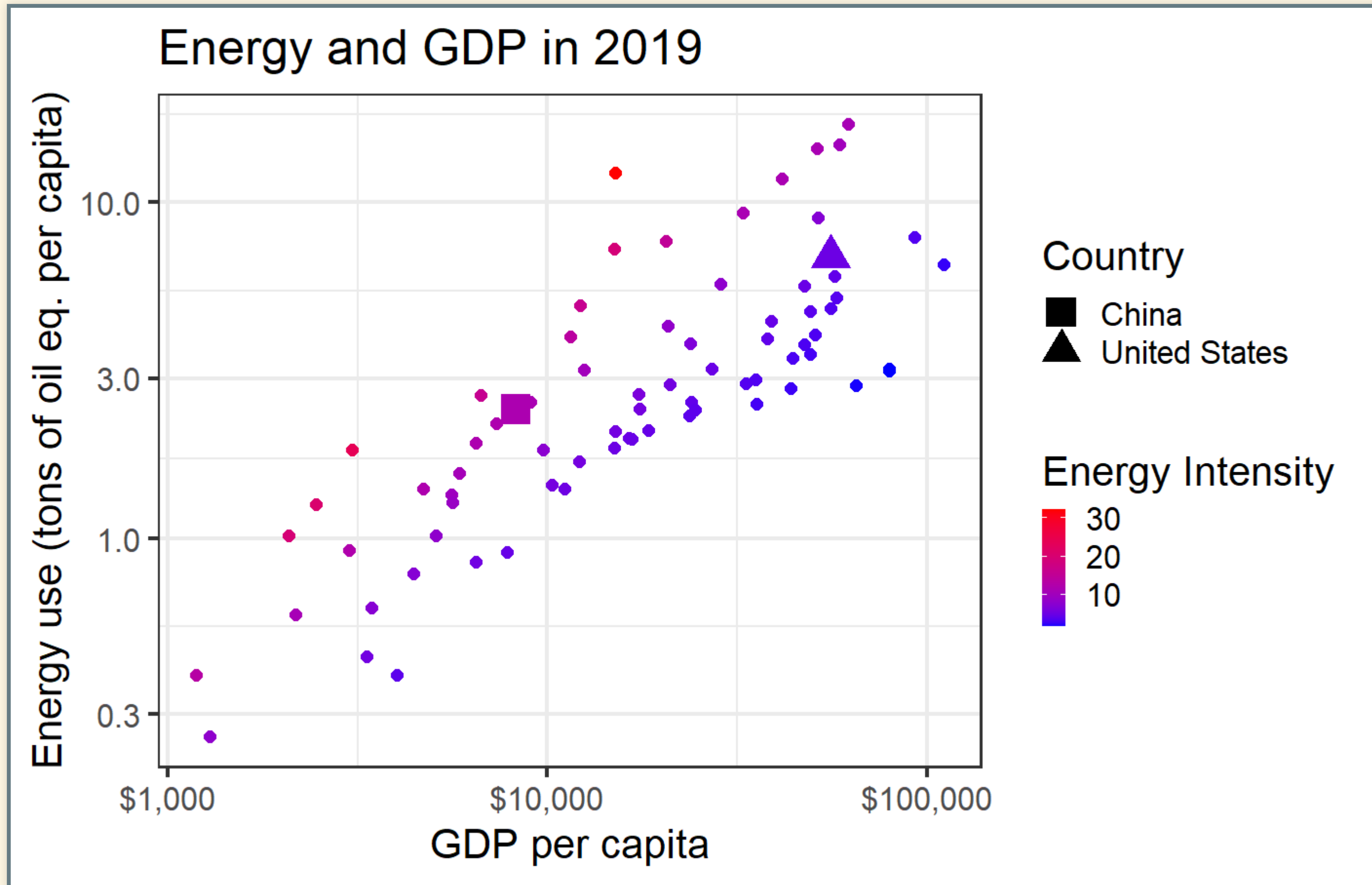
$g = G/P$  = per-capita GDP

$e = E/G$  = energy intensity of economy

$f = F/E$  = CO<sub>2</sub> intensity of energy supply

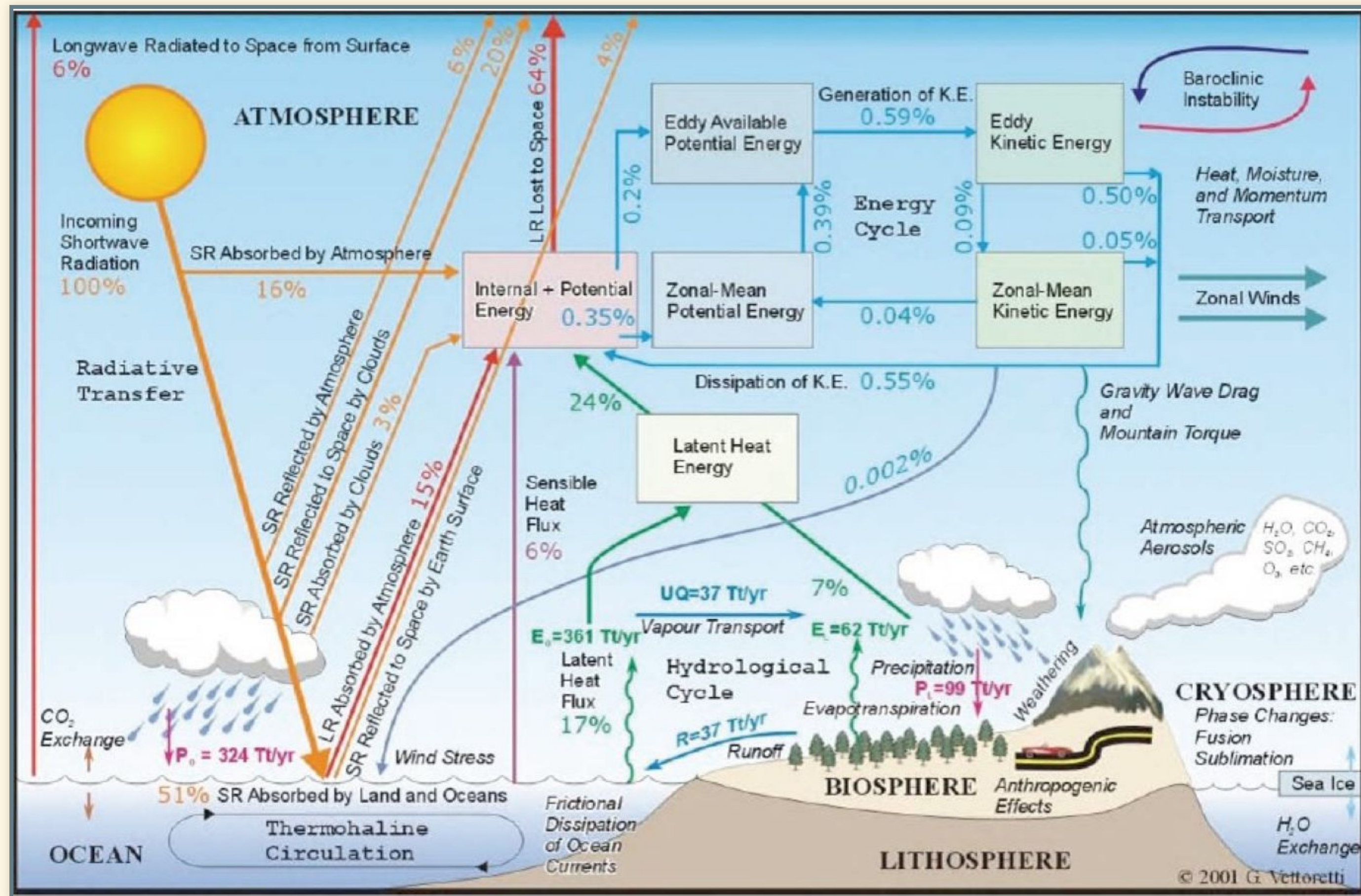


# Kaya Identity in Practice



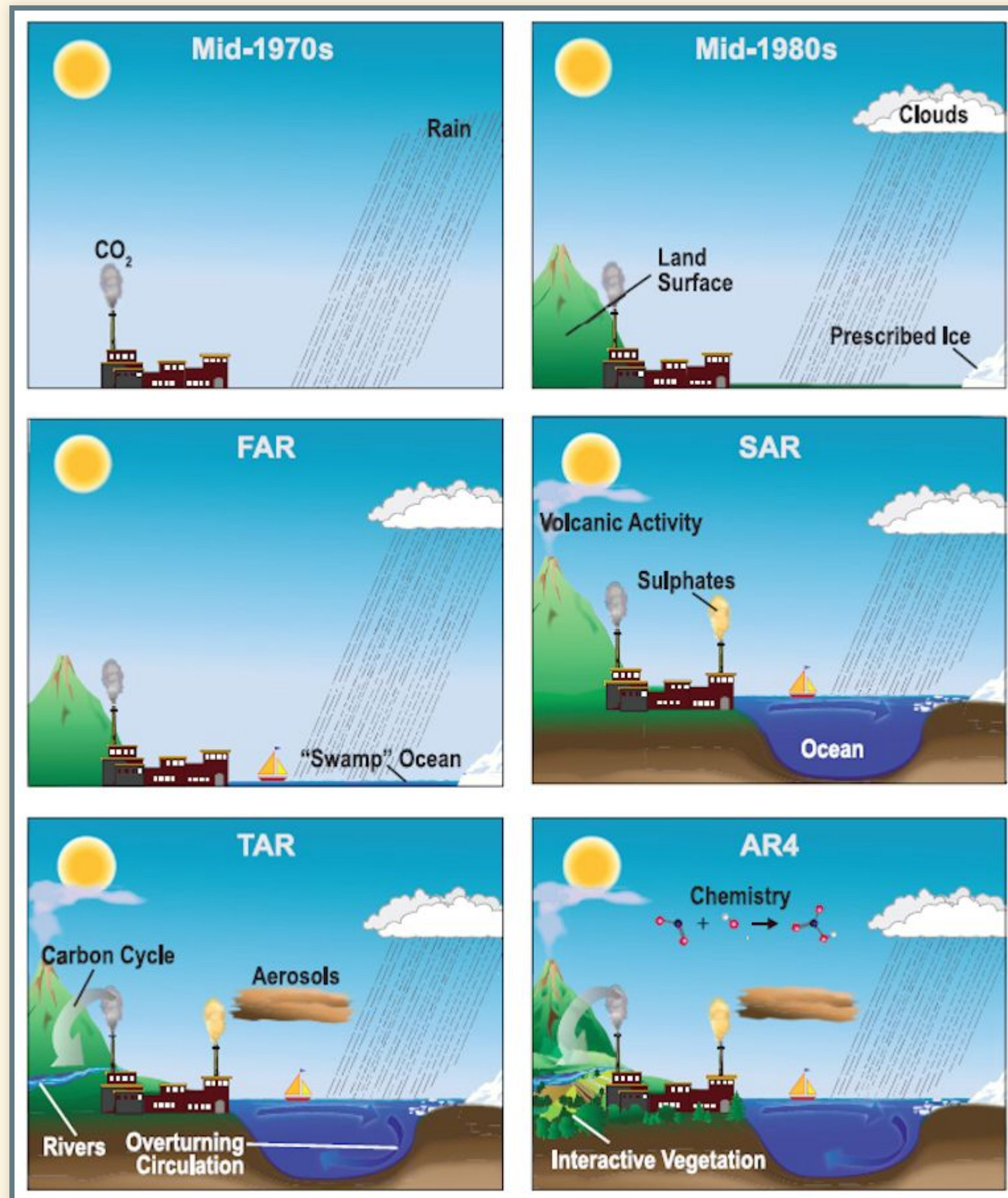
# Computer Models of Climate

# Computer Models of Climate



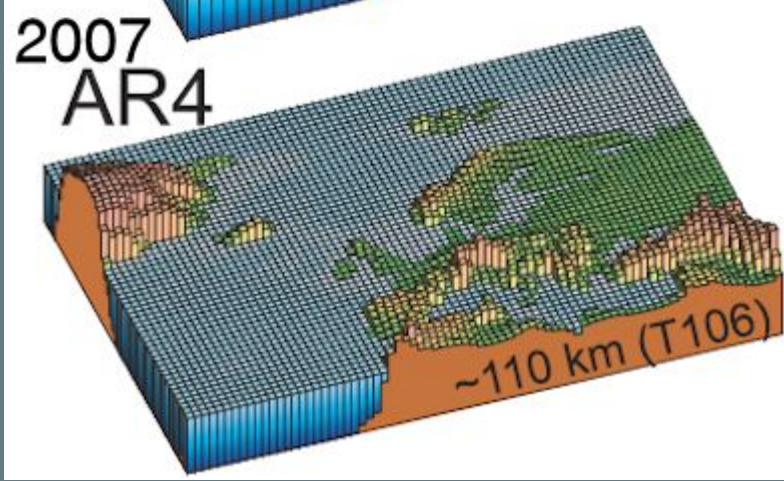
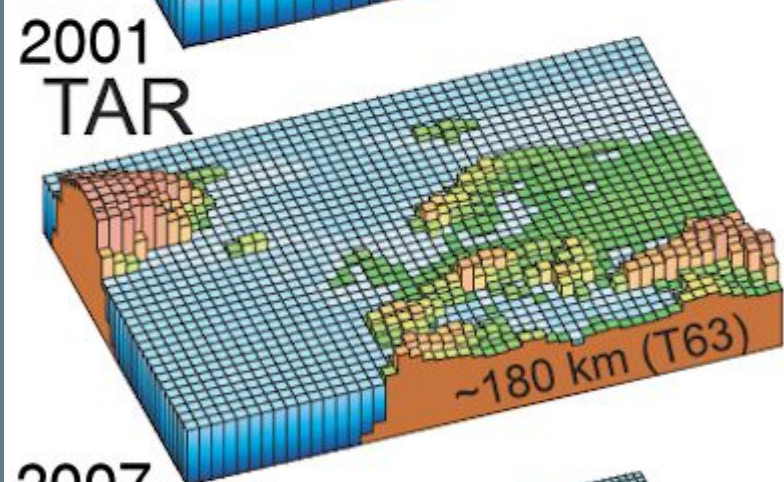
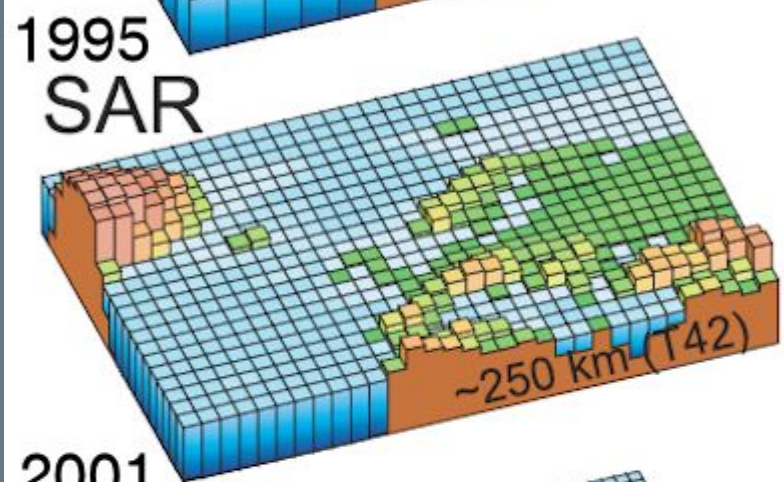
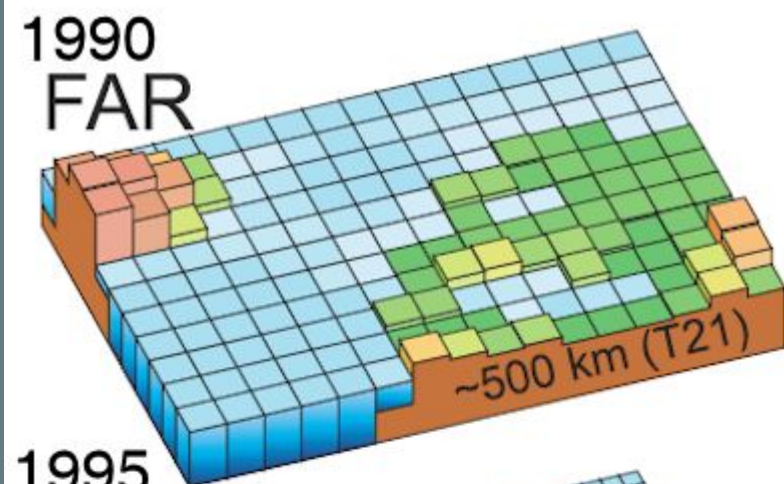


# Computer Models

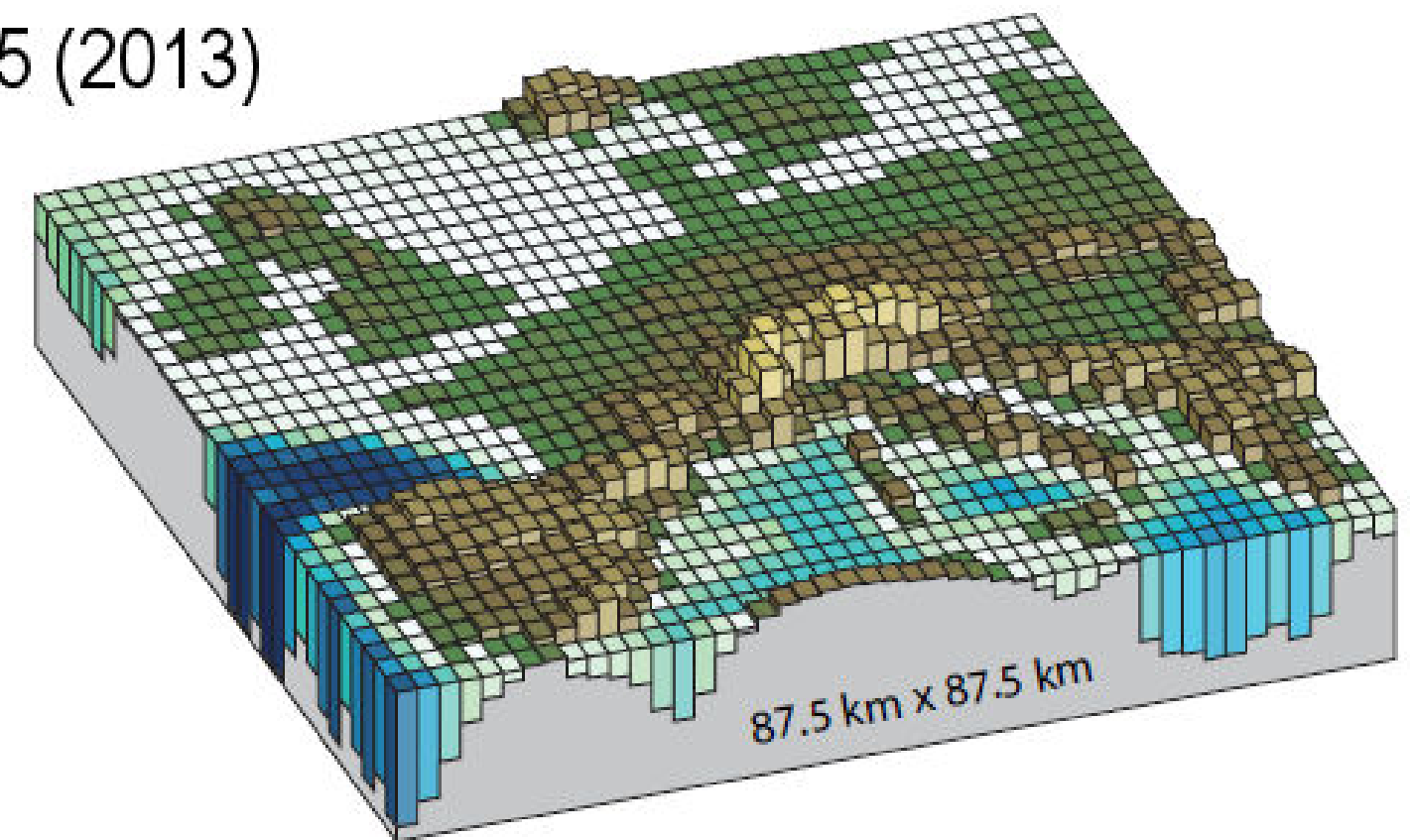




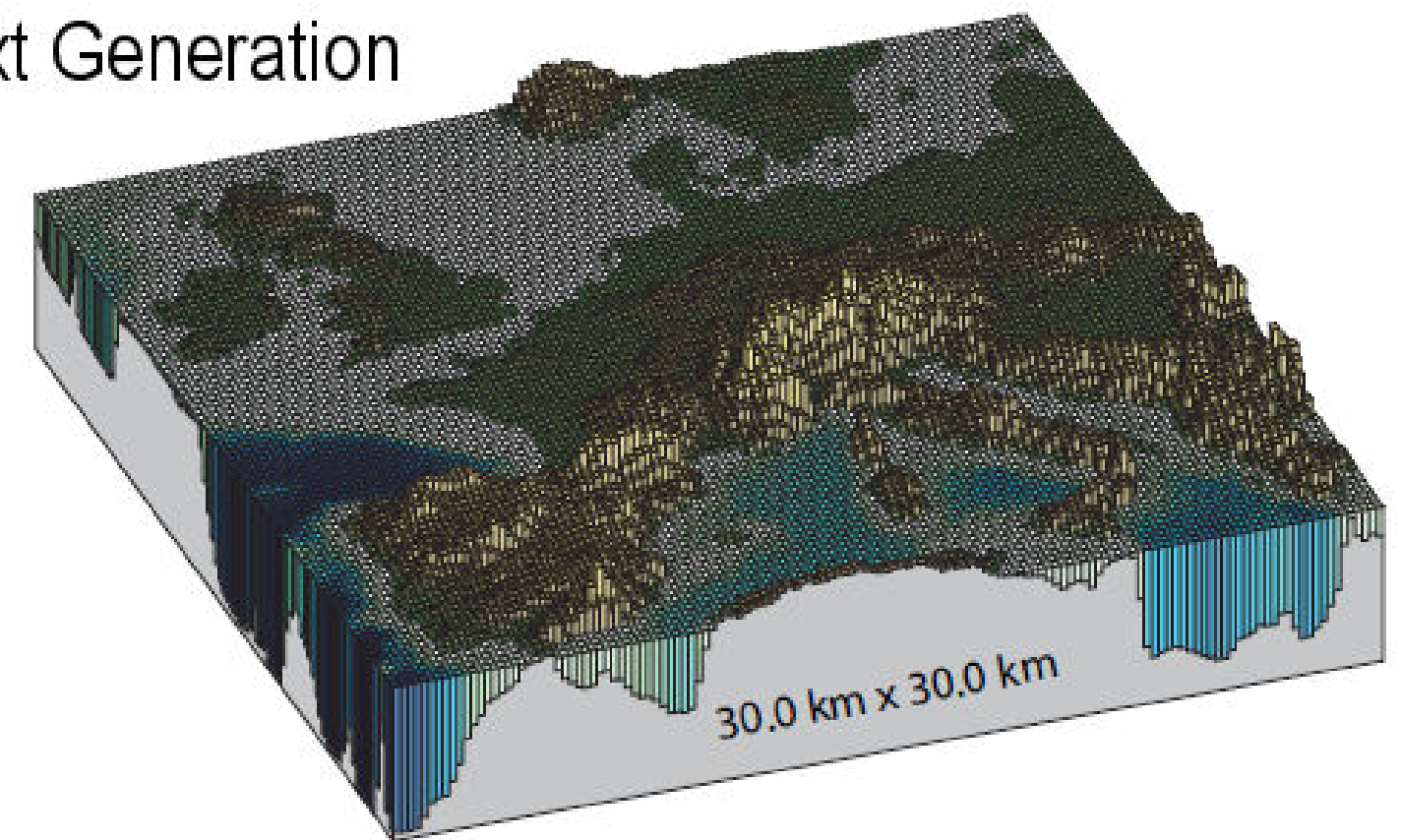
# Computer Models



AR5 (2013)

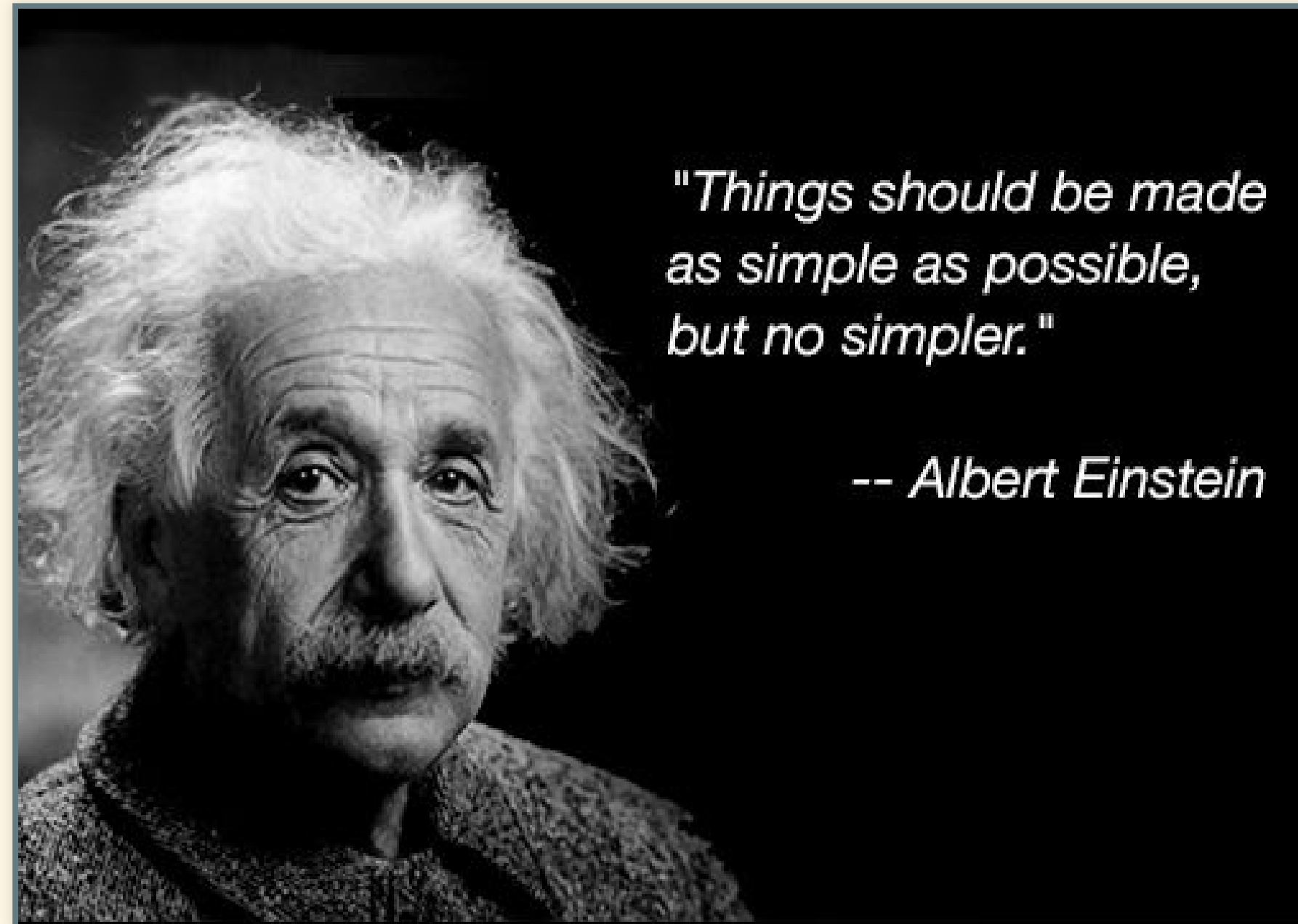


Next Generation



# Principles of Computer Modeling

- Make models as simple as possible:
  - Start simple
  - Add complexity only as needed
    - Different models for different purposes
  - Check model against real world

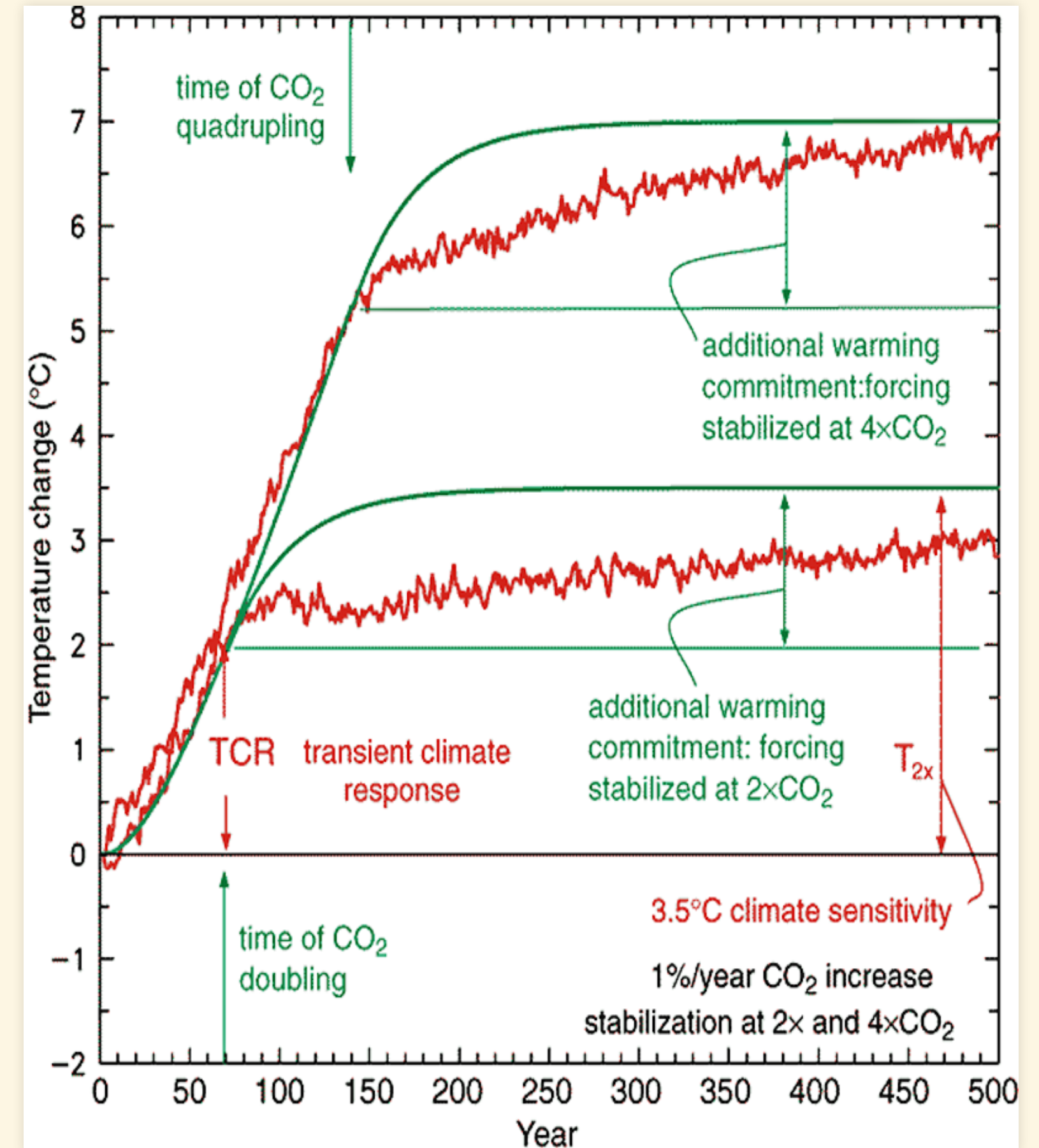


# Transient vs. Equilibrium Response



# Transient vs. Equilibrium Response

- Gradually raise  $\text{CO}_2$  and then stop.
- Planet takes time to heat up
  - Oceans absorb heat
  - Like pot of water on stove
- Transient response:  
 $\Delta T$  when  $\text{CO}_2$  stops changing
- Equilibrium response:  
Stable temperature (much later)
  - Green: Atmosphere & surface ocean
  - Red: Atmosphere, surface ocean, & deep ocean.
- Equilibrium takes many decades.





# Modeling for Science vs. Policy

# Modeling for Science vs. Policy

## Integrated Assessment Models (IAMS)

- Combine climate system and world economy
  - Emissions as a consequence of economic activity
    - Energy use for production (factories, etc.)
    - Energy use for consumption (households, etc.)
    - Farming: fertilizers, livestock, paddy fields, etc.
  - Climatic impacts on economy
    - Cost of severe weather
    - Sea level rise
    - Droughts & heat waves
    - ...
- **Optimize for greatest net economic output**

# Climate Projections

- Biggest uncertainty in predicting future climates is GHG emissions
  - We can predict consequences of emissions
  - We can't predict what emissions will be
- Scenarios and Pathways:
  - **Scenario**: possible future,
    - Story of economic & political development → resulting emissions
  - **Pathway**: possible future,
    - Trajectory of emissions → economic activity that might cause them
- Projections:
  - Conditional predictions:
    - “**If** emissions do this, **then** climate will do that.”

# Projections for future emissions in US:

	2010	2050	Growth rate
$g$ (\$/person)	42,300	83,495	1.7%
$ef$ (tons/\$million)	432	228	-1.6%
$P$ (millions)	309	393	0.6%
<b>Total Emissions <math>F</math></b> (million tons CO <sub>2</sub> )	<b>5,647</b>	<b>7,471</b>	$1.7 - 1.6 + 0.6 = \mathbf{0.7\%}$

## Projections for future world emissions:

	2010	2050	Growth rate
$g$ (\$/person)	9,780	22,654	2.1%
$ef$ (tons/\$million)	522	275	-1.6%
$P$ (millions)	6,410	9,188	0.9%
<b>Total Emissions <math>F</math></b> (million tons CO <sub>2</sub> )	<b>32,724</b>	<b>57,289</b>	$2.1 - 1.6 + 0.9 = \mathbf{1.4\%}$

# Uncertainties in Projections

Projections for future world emissions:

	2010	2050	2100	Growth rate
$g$ (\$/person)	9,780	22,654	64,737	2.1%
$ef$ (tons/\$million)	522	275	124	-1.6%
$P$ (millions)	6,410	9,188	14,409	0.9%
<b>Total Emissions <math>F</math></b> (million tons CO <sub>2</sub> )	<b>32,724</b>	<b>57,289</b>	<b>115,366</b>	<b>1.4%</b>

# Uncertainties in Projections

Projections for future world emissions  
with slightly different growth rates:

	2010	2050	2100	Growth rate	$\Delta$ rate
$g$ (\$/person)	9,780	24,541	77,505	2.3%	0.2%
$ef$ (tons/\$million)	522	298	148	-1.4%	0.2%
$P$ (millions)	6,410	9,563	15,766	1.0%	0.1%
<b>Total Emissions <math>F</math></b> (million tons CO <sub>2</sub> )	<b>32,724</b>	<b>69,973</b>	<b>180,930</b>	<b>1.9%</b>	0.5%
<b>Difference</b>		<b>12,684</b>	<b>65,564</b>	<b>0.5%</b>	
<b>Difference (%)</b>		<b>22%</b>	<b>57%</b>		